Genstat and SAS Programs for Recovering Interblock, Interrow-column, and Intergradient Information

by

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0. Abstrast

Genstat and SAS programs are presented for analyzing data from incomplete block and lattice rectangle designed experiments, both for intrablock and intrarow-column (fixed effects) and for recovery of interblock and interrow and intercolumn information (random effects). A triple lattice design with v = 9, r = 3, k = 3, and b = 9 and a balanced lattice square design with v = 16, r = 5, and with k = 4 rows and c = 4 columns in each complete block are used to illustrate the programs and outputs. In addition, programs and outputs are given for the situation when differential gradients appear within the incomplete blocks or within the rows (columns). The gradients are considered to be random effects and intergradient information is recovered and utilized in adjusting the treatment means. A comparison of the programs and outputs of Genstat and SAS is made and differences are noted.

1. Introduction

A description of GAUSS (Federer, 1995a) and SAS (Federer, 1995b) programs has appeared in Technical Reports of the Biometrics Unit. Federer and Wolfinger (1996) present a somewhat more general description using SAS. The purpose of this paper is to describe the procedures for recovering interblock (Section 2), interrow and intercolumn (Section 3), and interblock and intergradient (Section 4) information using the Genstat and SAS software packages. A comparison of the programs and of the outputs is made. The computer output is annotated in order to make it more easily understood. The annotations are in italic font.

Before presenting the programs, we make some comments about Genstat. There are three alternatives for the type of analyses envisioned here. These are:

1. Genstat ANOVA (analysis of variance) can be used for a generally balanced blocked design. A working definition of such a design is one for which, within an error stratum, all contrasts in a given main effect or interaction term are estimated with the same efficiency factor (Payne & Tobias, 1992): note that designs given by Federer (1955) and Cochran &

Cox (1957) satisfy this requirement. Wilkinson's (1970) method is used to estimate effects in the strata where they occur. ANOVA facilitates specification of blocking and treatment factors (Genstat factor equals SAS class variable), covariates, and general treatment contrasts. Of particular interest is the ability to specify pseudo-factors and thence accommodate partially balanced designs.

2. A regression approach may also be used. Sequential (nested elimination) sums of squares are produced (Type I in SAS terminology). The only way to produce SAS Type III sums of squares is to re-order the terms in the model and re-run the analysis, having the last one produce a Type III sum of squares.

3. REML may be used for fitting a variance component model. REML can print Wald statistics for testing null hypotheses on fixed effects in the model.

Genstat is flexible on what is to be printed and what is to be saved for subsequent analyses. For instance, standard errors of differences of means are printed by default, but standard errors of means may be optionally printed.

The versions used are Genstat 5 Release 3.1 (1993) and SAS 6.11 (1989, 1996).

The following designations for the different examples are:

SAS-1-1	Triple lattice using GLM ($v = 9$, $k = 3$, $r = 3$)
SAS-1-2	Triple lattice using REML, positive constraints
SAS-2-1	Lattice square using GLM ($v = 16$, $r = 5$)
SAS-2-2	Lattice square using REML, positive constraints
SAS-2-3	Lattice square using REML, no restrictions
SAS-3-1	Lattice square using GLM for rows and gradients in rows
SAS-3-2	Lattice square using REML, positive constraint, for rows and gradients
SAS-3-3	Lattice square using REML, no constraints, for rows and gradients
GN-1-0	Triple lattice using ANOVA program and output
GN-1-1	Triple lattice using regression program and output
GN-1-2	Triple lattice using REML program and output
GN-2-0	Lattice square using ANOVA program and output
GN-2-1	Lattice square using regression program and output
GN-2-2	Lattice square using REML program and output, positive constraints
GN-2-3	Lattice square using REML program and output, no constraints

GN-3-1	Lattice square with rows and gradients in rows, regression program
GN-3-2	Lattice square as above, REML program with positive constraints
GN-3-3	Lattice square as above, REML program with no constraints

Genstat can calculate 'combined means' when the design is such that treatment terms are estimated in more than one stratum. Combined means are averages of the estimates from each stratum weighted by efficiency factors divided by stratum variances.

2. Incomplete Block Design

Example XI-3 in Federer (1955) is used to illustrate the programming and output for an incomplete block design. The design for the example is a triple lattice with v = 9 treatments in incomplete blocks of k = 3 treatments, and r = 3 replicates (complete blocks). The data set is named fed933.dat. The intrablock analysis using Genstat is obtained using the following Genstat regression program for the output in GN-1-1:

```
units [27] factor r, b, t
open 'fed933.dat'; channel=2
read [channel=2] y, r, b, t;
model y
terms r/b + t
fit [print=accumulated; fprobability=yes] r/b + t
predict t
stop
```

The comparable SAS program with output shown in SAS-1-1 is obtained from the following using the general linear models procedure, PROC GLM:

```
data;
  infile 'fed933.dat';
  input y r b t;
proc glm;
  class r b t;
  model y = r b(r) t;
  lsmeans t;
```

The number of observations, 27 here, is usually specified in Genstat but not in SAS.
To show that incomplete blocks are nested within replicates (complete blocks) Genstat uses

r/b and SAS uses b(r). The factors r (replicate), b (incomplete block), and t (treatment) in Genstat are the class variables in SAS. The response variable is denoted by y in both packages. A comparison of the outputs for GN-1-1 and SAS-1-1 is given in Table 1.

To obtain treatment means recovering interblock information using ANOVA solutions for the variance components, the following Genstat analysis of variance program is used to obtain the output given in GN-1-0:

```
units [27]
factor r,b,t
open 'fed933.dat'; channel=2
read [channel=2] y, r, b, t
factor [levels=3] pa, pb, pc
calc pa = newlevels(t; !((1...3)3)
&    pb = newlevels(t; !(3(1...3))
&    pc = newlevels[t; !(1,2,3, 3,1,2, 2,3,1)
blocks r/b
treatments t//(pa+pb+pc)
anova [print=aovt,info,cbmeans; pse=means; fprobability=yes] y
stop
```

Pseudo-factors were generated from treatment levels with a newlevels function. Alternatively, they could have been included in the data. These pseudo-factors are the usual ones used for describing lattice designs: pa is the row factor of the orthogonal pseudo-structure, pb is the column factor, and pc is the 'diagonal'. The newlevels function simply maps treatment levels appropriately in pa, pb, and pc. The treatment formula t//(pa+pb+pc) indicates that terms following the pseudo-factor operator, //, are to fitted and sums of squares and effects therof added to give appropriate values for t in the printed tables.

The print option aovt says to print the ANOVA table; info says to print an information summary giving efficiency factors for terms which are not orthogonal; cbmeans ('combined means') says to print the least squares means with recovery of interblock information. For generally balanced designs, including this particular example, REML means are those obtained from the cbmeans option because the ANOVA and REML solutions for the variance components are the same. This is not true for all incomplete block designs. pse=means gives the standard error of means. The fprobability=yes option gives the probability of obtaining a larger F-value given that the null hypothesis is true.

The corresponding SAS program, PROC MIXED, for the above with the output in SAS-1-2, is:

```
data;
  infile 'fed933.dat';
  input y r b t;
proc mixed;
  class r b t;
  model y = t;
  random r b(r);
  lsmeans t;
```

Only fixed effects, treatments, appear in the model statement.

Using the Genstat variance components procedure, the following program produces the results given in GN-1-2:

```
unit [27]
factor r, b, t
open 'fed933.dat'; channel=2
read [channel=2] y, r, b, t
vcomponents [fixed=t] r/b
reml [print=means,comp,stra; pse=estimates] y
stop
```

A comparison of GN-1-0, GN-1-2, and SAS-1-2 outputs is made in Table 1. For this particular example the ANOVA and REML solutions for variance components are identical. This particular example illustrates an example of REML and ANOVA solutions being equal even when the parameters for the data set are non-orthogonal. This demonstrates that orthogonality is a sufficient but not a necessary condition for equality.

3. Lattice Square and Rectangle Designs with Rows and Columns

A Genstat regression program for obtaining the intrarow-column analysis of the balanced lattice square designed experiment presented in Table 12.5 of Cochran and Cox (1957) as given in GN-2-1 is:

```
units [80]
factor rep, row, col, treat
open 'lsgr1645.dat'; channel=2
```

```
read [channel=2] yield, rep, row, col, grad, treat
model yield
terms rep/(row+col) + treat
fit [print=accumulated; fprobability=yes] rep/(row+col) + treat
predict treat
```

The data set is named lsgr1645.dat and the factor `grad` is used for the analyses in Section 4. The corresponding SAS PROC GLM program for the output in SAS-2-1 is:

```
data;
  infile 'lsgr1645.dat';
  input yield rep row col grad treat;
proc glm;
  class rep row col treat;
  model yield = rep row(rep) col(rep) treat;
  lsmeans treat;
```

The program for obtaining the GN-2-0 ANOVA output for recovering interrow and intercolumn information using ANOVA solutions for variance components is:

```
units [80]
factor rep, row, col, treat
open 'lsgr1645.dat'; channel=2
read [channel=2] yield, rep, row, col, grad, treat
blocks rep/(row+col)
treatments treat
anova [print=aovt,info,cbmeans; pse=means; fprobability=yes] yield
stop
```

The code for obtaining the GN-2-2 variance component output with the constraint that all solutions to variance components are non-negative is:

```
units [80]
factor rep, row, col, treat
open 'lsgr1645.dat'; channel=2
read [channel=2] yield, rep, row, col, grad, treat
vcomponents [fixed=treat] rep/(row+col); constraints=positive
reml [print=means,comp,stra; pse=estimates] yield
```

```
stop
```

The code for obtaining the SAS-2-2 output is:

```
data;
  infile 'lsgr1645.dat';
  input yield rep row col grad treat;
proc mixed;
  class rep row(rep) col(rep) treat;
  model yield = rep row(rep) col(rep) treat;
  random rep row(rep) col(rep);
  lsmeans treat;
```

The Genstat variance components code for obtaining the output in GN-2-3 with no constraint on the REML solution for variance components is

```
units [80]
factor rep, row, col, treat
open 'lsgr1645.dat'; channel=2
read [channel=2] yield, rep, row, col, grad, treat
vcomponents [fixed=treat] rep/(row+col)
reml [print=means,comp,stra; pse=estimates] yield
stop
```

The code for obtaining the output in SAS-2-3 which uses REML solutions with no constraint on the solution for a variance component is

```
data;
  infile 'lsgr1645.dat';
  input yield rep row col grad treat;
proc mixed nobounds;
  class rep row col treat;
  model yield = treat;
  random rep row(rep) col(rep);
  lsmeans treat;
```

4. Incomplete Block or Lattice Rectangle Designs with Differential Gradients in Blocks

or in Rows

In certain experimental situations gradients may occur within the incomplete block or within the row (column) of the design. When this occurs the analysis in Sections 2 and 3 are inappropriate. Since the gradients or trends may vary from block to block or from row to row and these occur at random, an analysis recovering both interblock (interrow) and intergradient information is required in order to efficiently analyze the results from an experiment. Such an analysis was given by Federer (1996).

Although fixed covariates can be specified in Genstat ANOVA, random covariates cannot, and ANOVA cannot be used. Genstat regression code for obtaining the intrarow-gradient output in GN-3-1 for the data set lsgr1645.dat is:

```
units [80]
factor rep, row, treat
open 'lsgr1645.dat'; channel=2
read [channel=2] yield, rep, row, col, grad, treat
model yield
terms rep/row/grad + treat
fit [print=accumulated; fprobability=yes] rep/row/grad + treat
predict treat
stop
```

The comparable SAS PROC GLM program for obtaining the intrarow-gradient output given in SAS-3-1 is:

```
data;
  infile 'lsgr1645.dat';
  input yield, rep, row, col, grad, treat;
proc glm;
  class rep row treat;
  model yield = rep row(rep) grad*row(rep) treat;
  lsmeans treat;
```

The Genstat variance component code for obtaining the output in GN-3-2 using REML solutions with the positive constraint for the variance components is:

```
units [80]
factor rep, row, treat
```

```
open 'lsgr1645.dat'; channel=2
read [channel=2] yield, rep, row, col, grad, treat
vcomponents [fixed=treat] rep/row/grad; constraints=positive
reml [print=means,comp,stra; pterms=treat; pse=estimates] yield
stop
```

The SAS PROC MIXED program for obtaining the results in SAS-3-2 using REML solutions with positive constraints for the variance components is:

```
data;
  infile 'lsgr1645.dat';
  input yield rep row col grad treat;
proc mixed;
  class rep row treat;
  model yield = treat;
  random rep row(rep) grad*row(rep);
  lsmeans treat;
```

The Genstat variance component program for obtaining the output in GN-3-3 using REML solutions with no constraints for the variance components is:

```
units [80]
factor rep, row, treat
open 'lsgr1645.dat'; channel=2
read [channel=2] yield, rep, row, col, grad, treat
vcomponents [fixed=treat] rep/row/grad
reml [print=means,comp,stra; pterms=treat; pse=estimates] yield
```

The SAS PROC MIXED code for the results in SAS-3-3 using REML solutions with no constraints for the variance comnonents is:

```
data;
  infile 'lsgr1645.dat';
  input yield rep row col grad treat;
proc mixed nobounds;
  class rep row treat;
  random rep row(rep) grad*row(rep);
  lsmeans treat;
```

5. Discussion

Solutions for the variance components and the standard error and adjusted mena for treatment 1 are presented in Table 1. From the results in this Table, we note that the outputs of GN-x-1 = SAS-x-1, x = 1, 2, 3. This is the intrablock, intrrow-column, and intrrow-gradient or fixed effects case. The REML solutions for the varaince components with positive constraints are different for Genstat and for SAS, i.e., GN-x-2 results are not equal to SAS-x-2 results. It would appear that the two packages are using different boundary conditions on the solutions. The fact that the replicate variance component is negative for the ANOVA solution may account for this. When no constraints are used GN-2-3 = SAS-2-3 results and the results are fairly close to those for ANOVA. For GN-3-3 and SAS-3-3 with no constraints, the variance component solutions are the same but the treatment means are not. They should be equal but the reason they were not is unclear.

Following the outputs, the contents of the log from SAS is presented. These notes are an aid in interpreting the codes and outputs. Also, notes appear on each of the outputs explaining the various procedures used by the packages.

6. Literature Cited

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Table 1. Comparison of outputs from various programs.

	Variance components				Treatment 1	
Program	error		block	replicate	std error	mean*
GN-1-1	0.715	---	0.281	0.041	0.564	7.06
SAS-1-1	0.715	---	0.281	0.041	---	7.06
GN-1-0	0.715	---	---	---	0.539	7.21
GN-1-2	0.715	---	0.281	0.041	0.564	7.21
SAS-1-2	0.715	---	0.281	0.041	0.564	7.21
ANOVA	0.715	---	0.281	0.041	---	7.21
	error	column	row	replicate	std .error	mean
GN-2-1	22.67	4.88	15.26	-5.99	2.71	8.50
SAS-2-1	22.67	4.88	15.26	-5.99	---	8.50
GN-2-0	22.67	---	---	---	2.44	6.46
GN-2-2	22.64	4.93	15.34	0.00	2.62	6.46
SAS-2-2	23.86	3.17	10.91	0.00	2.57	6.09
GN-2-3	22.64	4.93	15.34	-5.99	2.38	6.46
SAS-2-3	22.64	4.93	15.34	-5.99	2.38	6.46
ANOVA	22.67	4.88	15.26	-5.99	---	6.45
	error	gradient	row	replicate	std .error	mean
GN-3-1	18.97	1.29	14.20	---	2.98	7.00
SAS-3-1	18.97	1.29	14.20	---	---	7.00
GN-3-2	18.62	1.38	15.87	0.00	---	5.88
SAS-3-2	18.77	1.40	11.26	0.00	2.48	5.50
GN-3-3	18.62	1.38	15.87	-4.64	---	5.88
SAS-3-3	18.62	1.38	15.87	-4.64	2.35	5.63
ANOVA	18.97	1.29	14.20	---	---	---

* Intrablock means ignore the treatment information in blocks while interblock means make use of this information in computing the means. Interrow-column equals interrowcol, interrow-gradient equals interrowgrad, intrarow-column equals intrarowcol, and intrarow-gradient equals intrarowgrad. REML with positive contraints on solutions of variance components are used for GN-x-2 and SAS-x-2, and REML with no constraints on the solutions for variance components are used for GN-x-3 and SAS-x-3, x = 1, 2, 3..

```
***** Analysis of variance *****

Variate: y

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

r stratum                  2     3.8519     1.9259

r.b stratum
t                          6    32.6667     5.4444

r.b.*Units* stratum
t                          8    56.1852     7.0231    9.83  <.001
Residual                  10     7.1481     0.7148

Total                     26    99.8519


***** Information summary *****

Model term                 e.f.  non-orthogonal terms

r.b stratum
  pa                      0.333
  pb                      0.333
  pc                      0.333

r.b.*Units* stratum
  pa                      0.667  r.b
  pb                      0.667  r.b
  pc                      0.667  r.b


* MESSAGE: the following units have large residuals.

r 1.00  b 3.00  *units* 2          1.07   s.e. 0.51
r 3.00  b 2.00  *units* 2         -1.04   s.e. 0.51


***** Tables of combined means *****

Variate: y

        t     1.00     2.00     3.00     4.00     5.00     6.00     7.00
       pa        1        2        3        1        2        3        1
       pb        1        1        1        2        2        2        3
       pc        1        2        3        3        1        2        2
              7.21     2.54     3.94     2.95     4.83     2.91     3.24

        t     8.00     9.00
       pa        2        3
       pb        3        3
       pc        3        1
              2.21     6.84


*** Standard errors of combined means ***

Table                    t
rep.                     3
e.s.e.               0.539
Except when comparing means with the same level(s) of
 pa                  0.523
 pb                  0.523
 pc                  0.523
```

***** Regression Analysis *****

*** Accumulated analysis of variance ***

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ r	2	3.8519	1.9259	2.69	0.116
+ r.b	6	32.6667	5.4444	7.62	0.003
+ t	8	56.1852	7.0231	9.83	<.001
Residual	10	7.1481	0.7148		
Total	26	99.8519	3.8405		

*** Predictions from regression model ***

These predictions are fitted values
adjusted with respect to some factors as specified below.

The predictions have been standardized by averaging
over the levels of some factors:

Factor	Weighting policy	Status of weights
b	Marginal weights	Constant over levels of other factors
r	Marginal weights	Constant over levels of other factors

Table contains predictions followed by standard errors

Response variate: y

t		
1.00	7.056	0.564
2.00	2.389	0.564
3.00	4.278	0.564
4.00	2.889	0.564
5.00	4.611	0.564
6.00	3.222	0.564
7.00	3.111	0.564
8.00	2.056	0.564
9.00	7.056	0.564

*** Estimated Variance Components ***

Random term	Component	S.e.
r	0.0407	0.2474
r.b	0.2815	0.4020
units	0.7148	0.3197

*** Approximate stratum variances ***

		Effective d.f.
r	1.9259	2.00
r.b	1.2778	6.00
units	0.7148	10.00

* Matrix of coefficients of components for each stratum *

r	9.00	3.00	1.00
r.b	0.00	2.00	1.00
units	0.00	0.00	1.00

*** Table of predicted means for Constant ***

1
4.074

Table has only one entry: standard error 0.2671

*** Table of predicted means for t ***

t	1.00	2.00	3.00	4.00	5.00
	7.211	2.544	3.936	2.951	4.829

t	6.00	7.00	8.00	9.00
	2.911	3.235	2.211	6.838

Standard errors:		
	Average	0.5640
	Maximum	0.5640
	Minimum	0.5640

***** Analysis of variance *****

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	4	31.56	7.89		
rep.row stratum					
treat	15	1844.55	122.97		
rep.col stratum					
treat	15	732.81	48.85		
rep.row.col stratum					
treat	15	319.45	21.30	0.94	0.535
Residual	30	680.17	22.67		
Total	79	3608.54			

***** Information summary *****

Model term	e.f.	non-orthogonal terms	
rep.row stratum			
treat	0.200		
rep.col stratum			
treat	0.200	rep.row	
rep.row.col stratum			
treat	0.600	rep.row	rep.col

* MESSAGE: the following units have large residuals.

rep 5.00 row 4.00 col 2.00 8.07 s.e. 2.92

***** Tables of combined means *****

Variate: yield

treat	1.00	2.00	3.00	4.00	5.00	6.00	7.00
	6.46	13.68	8.73	11.36	9.44	7.58	7.37
treat	8.00	9.00	10.00	11.00	12.00	13.00	14.00
	9.31	10.01	14.91	17.58	12.70	10.68	14.27
treat	15.00	16.00					
	9.28	11.10					

*** Standard errors of combined means ***

Table	treat
rep.	5
e.s.e.	2.439

***** Regression Analysis *****

*** Accumulated analysis of variance ***

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ rep	4	31.56	7.89	0.35	0.843
+ rep.row	15	1844.55	122.97	5.42	<.001
+ rep.col	15	732.81	48.85	2.15	0.036
+ treat	15	319.45	21.30	0.94	0.535
Residual	30	680.17	22.67		
Total	79	3608.54	45.68		

*** Predictions from regression model ***

These predictions are fitted values
adjusted with respect to some factors as specified below.

The predictions have been standardized by averaging
over the levels of some factors:

Factor	Weighting policy	Status of weights
col	Marginal weights	Constant over levels of other factors
row	Marginal weights	Constant over levels of other factors
rep	Marginal weights	Constant over levels of other factors

Table contains predictions followed by standard errors

Response variate: yield

treat		
1.00	8.50	2.71
2.00	13.90	2.71
3.00	9.59	2.71
4.00	11.39	2.71
5.00	8.76	2.71
6.00	9.38	2.71
7.00	7.60	2.71
8.00	8.73	2.71
9.00	9.24	2.71
10.00	13.48	2.71
11.00	16.11	2.71
12.00	12.04	2.71
13.00	8.75	2.71
14.00	14.72	2.71
15.00	8.91	2.71
16.00	13.39	2.71

```
* MESSAGE: Estimate for variance component rep at iteration   1 is negative
           A small positive value will be used next iteration
* MESSAGE: Estimate for variance component rep at iteration   2 is negative
           A small positive value will be used next iteration
* MESSAGE: Estimate for variance component rep at iteration   3 is negative
           A small positive value will be used next iteration

******** Warning (Code VC 21). Statement 1 on Line 7
Command: reml [print=means,comp,stra; pse=estimates] yield
Negative/zero component reset to a small positive value on final iteration

The results from this analysis should be compared with results obtained by
removing the  1 negative/zero component(s) from the RANDOM model, as estimates
of components and standard errors from the current model may be misleading.

*** Estimated Variance Components ***

Random term                Component        S.e.

rep                             0.00        5.18
rep.row                        15.34        8.45
rep.col                         4.93        4.87
*units*                        22.64        5.81

*** Approximate stratum variances ***

                                                   Effective d.f.
rep                                        103.76        4.00
rep.row                                     71.59       15.00
rep.col                                     38.05       14.63
*units*                                     22.64       30.37

* Matrix of coefficients of components for each stratum *


          rep       16.00        4.00        4.00        1.00
      rep.row        0.00        3.17        0.07        1.00
      rep.col        0.00        0.00        3.13        1.00
      *units*        0.00        0.00        0.00        1.00

*** Table of predicted means for Constant ***

                          1
                      10.90

Table has only one entry: standard error      1.139

*** Table of predicted means for treat ***

      treat         1.00        2.00        3.00        4.00        5.00
                    6.46       13.68        8.73       11.36        9.44


      treat         6.00        7.00        8.00        9.00       10.00
                    7.58        7.37        9.31       10.01       14.91


      treat        11.00       12.00       13.00       14.00       15.00
                   17.58       12.70       10.68       14.27        9.28


      treat        16.00
                   11.10

Standard errors:   Average         2.622
                   Maximum         2.622
                   Minimum         2.622
```

*** Estimated Variance Components ***

Random term	Component	S.e.
rep	-5.99	2.43
rep.row	15.34	8.45
rep.col	4.93	4.87
units	22.64	5.81

*** Approximate stratum variances ***

		Effective d.f.
rep	7.89	4.00
rep.row	71.59	15.00
rep.col	38.05	14.63
units	22.64	30.37

* Matrix of coefficients of components for each stratum *

rep	16.00	4.00	4.00	1.00
rep.row	0.00	3.17	0.07	1.00
rep.col	0.00	0.00	3.13	1.00
units	0.00	0.00	0.00	1.00

*** Negative variance components present:

* Fitting of fixed model terms is not sequential: effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

See Genstat Noticeboard for more details.

*** Table of predicted means for Constant ***

1
10.90

Table has only one entry: standard error 0.3141

*** Table of predicted means for treat ***

treat	1.00	2.00	3.00	4.00	5.00
	6.46	13.68	8.73	11.36	9.44

treat	6.00	7.00	8.00	9.00	10.00
	7.58	7.37	9.31	10.01	14.91

treat	11.00	12.00	13.00	14.00	15.00
	17.58	12.70	10.68	14.27	9.28

treat	16.00
	11.10

Standard errors:		
	Average	2.383
	Maximum	2.383
	Minimum	2.383

***** Regression Analysis *****

*** Accumulated analysis of variance ***

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ rep	4	31.56	7.89	0.42	0.796
+ rep.row	15	1844.55	122.97	6.48	<.001
+ grad.rep.row	20	910.98	45.55	2.40	0.020
+ treat	15	347.19	23.15	1.22	0.320
Residual	25	474.26	18.97		
Total	79	3608.54	45.68		

*** Predictions from regression model ***

These predictions are fitted values
adjusted with respect to some factors as specified below.

The predictions are based on fixed values of some variates:

Variate	Fixed value	Source of value
grad	0.	Mean of variate

The predictions have been standardized by averaging
over the levels of some factors:

Factor	Weighting policy	Status of weights
row	Marginal weights	Constant over levels of other factors
rep	Marginal weights	Constant over levels of other factors

Table contains predictions followed by standard errors

Response variate: yield

treat		
1.00	7.00	2.98
2.00	16.13	2.89
3.00	11.90	3.33
4.00	12.92	2.64
5.00	8.54	2.46
6.00	10.84	3.03
7.00	5.22	2.71
8.00	9.05	2.66
9.00	7.97	2.45
10.00	12.91	3.96
11.00	15.96	3.33
12.00	12.41	2.71
13.00	9.43	2.92
14.00	11.98	2.44
15.00	11.01	2.65
16.00	11.20	2.65

```
* MESSAGE: Estimate for variance component rep at iteration   1 is negative
           A small positive value will be used next iteration
* MESSAGE: Estimate for variance component rep at iteration   2 is negative
           A small positive value will be used next iteration
* MESSAGE: Estimate for variance component rep at iteration   3 is negative
           A small positive value will be used next iteration
* MESSAGE: Estimate for variance component rep at iteration   4 is negative
           A small positive value will be used next iteration

******** Warning (Code VC 38). Statement 1 on Line 27
Command: reml [print=means,comp,stra; pterms=treat; pse=estimates] yield
Value of deviance at final iteration larger than at previous iteration(s)

Minimum deviance = 313.712: value at final iteration = 313.797

******** Warning (Code VC 21). Statement 1 on Line 27
Command: reml [print=means,comp,stra; pterms=treat; pse=estimates] yield
Negative/zero component reset to a small positive value on final iteration

The results from this analysis should be compared with results obtained by
removing the  1 negative/zero component(s) from the RANDOM model, as estimates
of components and standard errors from the current model may be misleading.

*** Estimated Variance Components ***

Random term                 Component         S.e.

rep                              0.00         4.15
rep.row                         15.87         8.20
rep.row.grad                     1.38         0.89
*units*                         18.62         5.15

*** Approximate stratum variances ***
                                                  Effective d.f.
rep                                      82.14         4.00
rep.row                                  68.93        15.00
rep.row.grad                             40.46        18.85
*units*                                  18.62        26.15

* Matrix of coefficients of components for each stratum *

          rep      16.00         4.00         0.00         1.00
      rep.row       0.00         3.13         0.46         1.00
 rep.row.grad       0.00         0.00        15.82         1.00
      *units*       0.00         0.00         0.00         1.00

* MESSAGE: Standard errors of means are not available.
           This happens when there are fixed terms in the absorbing factor model
           or if the algorithm has not reached convergence, when SEs may be
           inaccurate.

           SEDs are available using PSE=difference or PSE=alldifferences

*** Table of predicted means for treat ***

      treat        1.00         2.00         3.00         4.00         5.00
                   5.88        15.01         9.51        12.33         9.62

      treat        6.00         7.00         8.00         9.00        10.00
                   8.48         6.54         9.60         9.48        15.53

      treat       11.00        12.00        13.00        14.00        15.00
                  17.64        13.51        10.87        13.29        10.60

      treat       16.00
                  10.58
```

*** Estimated Variance Components ***

Random term	Component	S.e.
rep	-4.64	2.04
rep.row	15.87	8.20
rep.row.grad	1.38	0.89
units	18.62	5.15

*** Approximate stratum variances ***

		Effective d.f.
rep	7.89	4.00
rep.row	68.93	15.00
rep.row.grad	40.46	18.85
units	18.62	26.15

* Matrix of coefficients of components for each stratum *

rep	16.00	4.00	0.00	1.00
rep.row	0.00	3.13	0.46	1.00
rep.row.grad	0.00	0.00	15.82	1.00
units	0.00	0.00	0.00	1.00

*** Negative variance components present:

* Fitting of fixed model terms is not sequential: effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

See Genstat Noticeboard for more details.

* MESSAGE: Standard errors of means are not available.
This happens when there are fixed terms in the absorbing factor model or if the algorithm has not reached convergence, when SEs may be inaccurate.

SEDs are available using PSE=difference or PSE=alldifferences

*** Table of predicted means for treat ***

treat	1.00	2.00	3.00	4.00	5.00
	5.88	15.01	9.51	12.33	9.62

treat	6.00	7.00	8.00	9.00	10.00
	8.48	6.54	9.60	9.48	15.53

treat	11.00	12.00	13.00	14.00	15.00
	17.64	13.51	10.87	13.29	10.60

treat	16.00
	10.58

General Linear Models Procedure

Dependent Variable: Y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	92.70370370	5.79398148	8.11	0.0010
Error	10	7.14814815	0.71481481		
Corrected Total	26	99.85185185			

R-Square	C.V.	Root MSE	Y Mean
0.928412	20.75238	0.845467	4.074074

Source	DF	Type I SS	Mean Square	F Value	Pr > F
R	2	3.85185185	1.92592593	2.69	0.1159
B(R)	6	32.66666667	5.44444444	7.62	0.0028
T	8	56.18518519	7.02314815	9.83	0.0008

Source	DF	Type III SS	Mean Square	F Value	Pr > F
R	2	3.85185185	1.92592593	2.69	0.1159
B(R)	6	7.66666667	1.27777778	1.79	0.1989
T	8	56.18518519	7.02314815	9.83	0.0008

Least Squares Means

T	Y LSMEAN
1	7.05555556
2	2.38888889
3	4.27777778
4	2.88888889
5	4.61111111
6	3.22222222
7	3.11111111
8	2.05555556
9	7.05555556

REML Estimation Iteration History

Iteration	Evaluations	Objective	Criterion
0	1	28.54212819	
1	1	27.31174135	0.00000000

Convergence criteria met.

Covariance Parameter Estimates (REML)

Cov Parm	Ratio	Estimate	Std Error	Z	Pr > |Z|
R	0.05699482	0.04074074	0.24743813	0.16	0.8692
B(R)	0.39378238	0.28148148	0.40200458	0.70	0.4838
Residual	1.00000000	0.71481481	0.31967490	2.24	0.0253

Model Fitting Information for Y

Description	Value
Observations	27.0000
Variance Estimate	0.7148
Standard Deviation Estimate	0.8455
REML Log Likelihood	-30.1968
Akaike's Information Criterion	-33.1968
Schwarz's Bayesian Criterion	-34.5323
-2 REML Log Likelihood	60.3935

Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
T	8	10	11.69	0.0004

Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
T 1	7.21095008	0.56402138	10	12.78	0.0001
T 2	2.54428341	0.56402138	10	4.51	0.0011
T 3	3.93590982	0.56402138	10	6.98	0.0001
T 4	2.95104670	0.56402138	10	5.23	0.0004
T 5	4.82866345	0.56402138	10	8.56	0.0001
T 6	2.91143317	0.56402138	10	5.16	0.0004
T 7	3.23542673	0.56402138	10	5.74	0.0002
T 8	2.21095008	0.56402138	10	3.92	0.0029
T 9	6.83800322	0.56402138	10	12.12	0.0001

General Linear Models Procedure

Dependent Variable: YIELD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	49	2928.370083	59.762655	2.64	0.0029
Error	30	680.167917	22.672264		
Corrected Total	79	3608.538000			

R-Square	C.V.	Root MSE	YIELD Mean
0.811511	43.66382	4.761540	10.90500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	4	31.563000	7.890750	0.35	0.8433
ROW(REP)	15	1844.545000	122.969667	5.42	0.0001
COL(REP)	15	732.810000	48.854000	2.15	0.0359
TREAT	15	319.452083	21.296806	0.94	0.5350

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	31.563000	7.890750	0.35	0.8433
ROW(REP)	15	1026.755833	68.450389	3.02	0.0049
COL(REP)	15	559.589583	37.305972	1.65	0.1197
TREAT	15	319.452083	21.296806	0.94	0.5350

Least Squares Means

TREAT	YIELD LSMEAN
1	8.4966667
2	13.8966667
3	9.5883333
4	11.3883333
5	8.7633333
6	9.3800000
7	7.5966667
8	8.7300000
9	9.2383333
10	13.4800000
11	16.1133333
12	12.0383333
13	8.7466667
14	14.7216667
15	8.9133333
16	13.3883333

REML Estimation Iteration History

Iteration	Evaluations	Objective	Criterion
0	1	320.75064929	
1	3	316.36234198	0.00037412
2	1	316.29770396	0.00000930
3	1	316.29620730	0.00000001

Convergence criteria met.

Covariance Parameter Estimates (REML)

Cov Parm	Ratio	Estimate	Std Error	Z	Pr > |Z|
REP	0.00000000	0.00000000	.	.	.
ROW(REP)	0.45722783	10.91105649	6.44537059	1.69	0.0905
COL(REP)	0.13280685	3.16923625	4.23588385	0.75	0.4543
Residual	1.00000000	23.86350057	6.49142711	3.68	0.0002

Model Fitting Information for YIELD

Description	Value
Observations	80.0000
Variance Estimate	23.8635
Standard Deviation Estimate	4.8850
REML Log Likelihood	-216.960
Akaike's Information Criterion	-220.960
Schwarz's Bayesian Criterion	-225.278
-2 REML Log Likelihood	433.9203

Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TREAT	15	30	1.71	0.1028

Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
TREAT 1	6.08950412	2.56635025	30	2.37	0.0243
TREAT 2	13.73133430	2.56635025	30	5.35	0.0001
TREAT 3	8.49247317	2.56635025	30	3.31	0.0024
TREAT 4	11.34388365	2.56635025	30	4.42	0.0001
TREAT 5	9.56248023	2.56635025	30	3.73	0.0008
TREAT 6	7.29598980	2.56635025	30	2.84	0.0080
TREAT 7	7.29811356	2.56635025	30	2.84	0.0080
TREAT 8	9.41317933	2.56635025	30	3.67	0.0009
TREAT 9	10.11393982	2.56635025	30	3.94	0.0004
TREAT 10	15.18439125	2.56635025	30	5.92	0.0001
TREAT 11	17.90505021	2.56635025	30	6.98	0.0001
TREAT 12	12.84656061	2.56635025	30	5.01	0.0001
TREAT 13	11.03255122	2.56635025	30	4.30	0.0002
TREAT 14	14.25004172	2.56635025	30	5.55	0.0001
TREAT 15	9.29444810	2.56635025	30	3.62	0.0011
TREAT 16	10.62605892	2.56635025	30	4.14	0.0003

REML Estimation Iteration History

Iteration	Evaluations	Objective	Criterion
0	1	320.75064929	
1	41	310.15497280	0.00000475
2	1	310.15424529	0.00000114
3	24	310.15424529	0.00000000

Convergence criteria met.

Covariance Parameter Estimates (REML)

Cov Parm	Ratio	Estimate	Std Error	Z	Pr > |Z|
REP	-0.26454875	-5.98895464	2.42182616	-2.47	0.0134
ROW(REP)	0.67770618	15.34216856	8.44222629	1.82	0.0692
COL(REP)	0.21762904	4.92676846	4.86133265	1.01	0.3108
Residual	1.00000000	22.63837785	5.80089833	3.90	0.0001

Model Fitting Information for YIELD

Description	Value
Observations	80.0000
Variance Estimate	22.6384
Standard Deviation Estimate	4.7580
REML Log Likelihood	-213.889
Akaike's Information Criterion	-217.889
Schwarz's Bayesian Criterion	-222.207
-2 REML Log Likelihood	427.7784
Null Model LRT Chi-Square	10.5964
Null Model LRT DF	3.0000
Null Model LRT P-Value	0.0141

Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TREAT	15	30	1.56	0.1456

Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
TREAT 1	6.45676767	2.38280328	30	2.71	0.0110
TREAT 2	13.68309239	2.38280328	30	5.74	0.0001
TREAT 3	8.73034761	2.38280328	30	3.66	0.0010
TREAT 4	11.35763527	2.38280328	30	4.77	0.0001
TREAT 5	9.43774590	2.38280328	30	3.96	0.0004
TREAT 6	7.58451065	2.38280328	30	3.18	0.0034
TREAT 7	7.37176660	2.38280328	30	3.09	0.0043
TREAT 8	9.31379607	2.38280328	30	3.91	0.0005
TREAT 9	10.01108798	2.38280328	30	4.20	0.0002
TREAT 10	14.90910163	2.38280328	30	6.26	0.0001
TREAT 11	17.58469554	2.38280328	30	7.38	0.0001
TREAT 12	12.69926655	2.38280328	30	5.33	0.0001
TREAT 13	10.68282986	2.38280328	30	4.48	0.0001
TREAT 14	14.27303348	2.38280328	30	5.99	0.0001
TREAT 15	9.28301517	2.38280328	30	3.90	0.0005
TREAT 16	11.10130763	2.38280328	30	4.66	0.0001

General Linear Models Procedure

Dependent Variable: YIELD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	54	3134.276383	58.042155	3.06	0.0016
Error	25	474.261617	18.970465		
Corrected Total	79	3608.538000			

R-Square	C.V.	Root MSE	YIELD Mean
0.868572	39.94048	4.355510	10.90500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	4	31.563000	7.890750	0.42	0.7955
ROW(REP)	15	1844.545000	122.969667	6.48	0.0001
GRAD*ROW(REP)	20	910.980000	45.549000	2.40	0.0198
TREAT	15	347.188383	23.145892	1.22	0.3202

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	31.5630000	7.8907500	0.42	0.7955
ROW(REP)	15	884.1127443	58.9408496	3.11	0.0060
GRAD*ROW(REP)	20	765.4958827	38.2747941	2.02	0.0488
TREAT	15	347.1883827	23.1458922	1.22	0.3202

Least Squares Means

TREAT	YIELD LSMEAN
1	7.0031624
2	16.1303818
3	11.9046018
4	12.9165862
5	8.5398621
6	10.8440679
7	5.2166649
8	9.0500145
9	7.9690246
10	12.9124117
11	15.9602515
12	12.4141825
13	9.4348069
14	11.9770655
15	11.0053112
16	11.2016047

REML Estimation Iteration History

Iteration	Evaluations	Objective	Criterion
0	1	320.75064929	
1	3	313.44983320	0.00067288
2	1	313.33214125	0.00002820
3	1	313.32759167	0.00000006
4	1	313.32758215	0.00000000

Convergence criteria met.

Covariance Parameter Estimates (REML)

Cov Parm	Ratio	Estimate	Std Error	Z	Pr > |Z|
REP	0.00000000	0.00000000	.	.	.
ROW(REP)	0.59973661	11.25726995	5.94732994	1.89	0.0584
GRAD*ROW(REP)	0.07445524	1.39755146	0.89873110	1.56	0.1199
Residual	1.00000000	18.77035654	5.16728433	3.63	0.0003

Model Fitting Information for YIELD

Description	Value
Observations	80.0000
Variance Estimate	18.7704
Standard Deviation Estimate	4.3325
REML Log Likelihood	-215.476
Akaike's Information Criterion	-219.476
Schwarz's Bayesian Criterion	-223.794
-2 REML Log Likelihood	430.9517

Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TREAT	15	25	1.91	0.0736

Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
TREAT 1	5.50387803	2.48063331	25	2.22	0.0358
TREAT 2	15.04767639	2.47702021	25	6.07	0.0001
TREAT 3	8.84838625	2.57255200	25	3.44	0.0021
TREAT 4	12.05491597	2.39508859	25	5.03	0.0001
TREAT 5	9.39722793	2.32204120	25	4.05	0.0004
TREAT 6	8.26894654	2.48159219	25	3.33	0.0027
TREAT 7	6.18173650	2.39795747	25	2.58	0.0162
TREAT 8	9.37746781	2.39618712	25	3.91	0.0006
TREAT 9	9.16385288	2.32153157	25	3.95	0.0006
TREAT 10	15.42776142	2.68095394	25	5.75	0.0001
TREAT 11	17.68686255	2.57200068	25	6.88	0.0001
TREAT 12	13.38207577	2.39799731	25	5.58	0.0001
TREAT 13	10.71280675	2.47872595	25	4.32	0.0002
TREAT 14	13.19930291	2.32128567	25	5.69	0.0001
TREAT 15	10.20507704	2.39541366	25	4.26	0.0003
TREAT 16	10.02202526	2.39560253	25	4.18	0.0003

REML Estimation Iteration History

Iteration	Evaluations	Objective	Criterion
0	1	320.75064929	
1	5	308.06036192	0.00017420
2	1	308.04470799	0.00008138
3	2	308.04247357	0.00000223
4	2	308.04244876	0.00000150
5	1	308.04219439	0.00000017
6	26	308.04219439	0.00000004
7	1	308.04218873	0.00000000

Convergence criteria met.

Covariance Parameter Estimates (REML)

Cov Parm	Ratio	Estimate	Std Error	Z	Pr > |Z|
REP	-0.24912657	-4.63861466	2.05902187	-2.25	0.0243
ROW(REP)	0.85245362	15.87226891	8.25652647	1.92	0.0546
GRAD*ROW(REP)	0.07412659	1.38020071	0.89320859	1.55	0.1223
Residual	1.00000000	18.61951020	5.11329182	3.64	0.0003

Model Fitting Information for YIELD

Description	Value
Observations	80.0000
Variance Estimate	18.6195
Standard Deviation Estimate	4.3150
REML Log Likelihood	-212.833
Akaike's Information Criterion	-216.833
Schwarz's Bayesian Criterion	-221.151
-2 REML Log Likelihood	425.6663
Null Model LRT Chi-Square	12.7085
Null Model LRT DF	3.0000
Null Model LRT P-Value	0.0053

Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TREAT	15	25	1.75	0.1040

Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
TREAT 1	5.63031338	2.35004897	25	2.40	0.0244
TREAT 2	14.76141244	2.34596506	25	6.29	0.0001
TREAT 3	9.26001109	2.45008876	25	3.78	0.0009
TREAT 4	12.08431623	2.25657069	25	5.36	0.0001
TREAT 5	9.37530471	2.17668826	25	4.31	0.0002
TREAT 6	8.23407483	2.35114871	25	3.50	0.0018
TREAT 7	6.28847743	2.25983390	25	2.78	0.0101
TREAT 8	9.34934504	2.25781208	25	4.14	0.0003
TREAT 9	9.22923310	2.17610629	25	4.24	0.0003
TREAT 10	15.27822847	2.56799897	25	5.95	0.0001
TREAT 11	17.38603297	2.44947229	25	7.10	0.0001
TREAT 12	13.25823393	2.25987666	25	5.87	0.0001
TREAT 13	10.61749416	2.34788188	25	4.52	0.0001
TREAT 14	13.03810178	2.17582751	25	5.99	0.0001
TREAT 15	10.35370338	2.25694421	25	4.59	0.0001
TREAT 16	10.33571708	2.25715433	25	4.58	0.0001

```
      /* sas-1-1.sas.  Triple lattice  */
    options ls=78;
    data;
      infile 'fed933.dat';
      input y r b t;

NOTE: The infile 'fed933.dat' is:
      File Name=/home/jb/wk/federer/fed933.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=216

NOTE: 27 records were read from the infile 'fed933.dat'.
      The minimum record length was 7.
      The maximum record length was 7.
NOTE: The data set WORK.DATA1 has 27 observations and 4 variables.
NOTE: DATA statement used:
      real time           0.070 seconds
      cpu time            0.070 seconds


    proc glm;
      class r b t;
      model y = r b(r) t;
      lsmeans t;
NOTE: The PROCEDURE GLM printed pages 1-3.
NOTE: PROCEDURE GLM used:
      real time           0.186 seconds
      cpu time            0.059 seconds



      /* sas-1-2.sas.  Triple lattice  */
    options ls=78;
    data;
      infile 'fed933.dat';
      input y r b t;

NOTE: The infile 'fed933.dat' is:
      File Name=/home/jb/wk/federer/fed933.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=216

NOTE: 27 records were read from the infile 'fed933.dat'.
      The minimum record length was 7.
      The maximum record length was 7.
NOTE: The data set WORK.DATA1 has 27 observations and 4 variables.
NOTE: DATA statement used:
      real time           0.075 seconds
      cpu time            0.068 seconds


    proc mixed;
      class r b t;
      model y = t;
      random r b(r);
      lsmeans t;
NOTE: The PROCEDURE MIXED printed pages 1-2.
NOTE: PROCEDURE MIXED used:
      real time           0.103 seconds
      cpu time            0.075 seconds
```

```
          /* sas-2-1.sas.  Lattice square */
        options ls=78;
        data;
          infile 'lsgr1645.dat';
          input yield rep row col grad treat;

NOTE: The infile 'lsgr1645.dat' is:
      File Name=/home/jb/wk/federer/lsgr1645.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=1236

NOTE: 80 records were read from the infile 'lsgr1645.dat'.
      The minimum record length was 13.
      The maximum record length was 16.
NOTE: The data set WORK.DATA1 has 80 observations and 6 variables.
NOTE: DATA statement used:
      real time           0.069 seconds
      cpu time            0.070 seconds


        proc glm;
          class rep row col treat;
          model yield = rep row(rep) col(rep) treat;
          lsmeans treat;
NOTE: The PROCEDURE GLM printed pages 1-3.
NOTE: PROCEDURE GLM used:
      real time           0.577 seconds
      cpu time            0.142 seconds


          /* sas-2-2.sas.  Lattice square */
        options ls=78;
        data;
          infile 'lsgr1645.dat';
          input yield rep row col grad treat;

NOTE: The infile 'lsgr1645.dat' is:
      File Name=/home/jb/wk/federer/lsgr1645.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=1236

NOTE: 80 records were read from the infile 'lsgr1645.dat'.
      The minimum record length was 13.
      The maximum record length was 16.
NOTE: The data set WORK.DATA1 has 80 observations and 6 variables.
NOTE: DATA statement used:
      real time           0.270 seconds
      cpu time            0.069 seconds


        proc mixed;
          class rep row col treat;
          model yield = treat;
          random rep row(rep) col(rep);
          lsmeans treat;
NOTE: Estimated G matrix is not positive definite.
NOTE: At least one W.D format was too small for the number to be printed. The
      decimal may be shifted by the "BEST" format.
NOTE: The PROCEDURE MIXED printed pages 1-2.
NOTE: PROCEDURE MIXED used:
      real time           0.243 seconds
      cpu time            0.192 seconds
```

```
          /* sas-2-3.sas.  Lattice square */
        options ls=78;
        data;
          infile 'lsgr1645.dat';
          input yield rep row col grad treat;

NOTE: The infile 'lsgr1645.dat' is:
      File Name=/home/jb/wk/federer/lsgr1645.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=1236

NOTE: 80 records were read from the infile 'lsgr1645.dat'.
      The minimum record length was 13.
      The maximum record length was 16.
NOTE: The data set WORK.DATA1 has 80 observations and 6 variables.
NOTE: DATA statement used:
      real time           0.077 seconds
      cpu time            0.077 seconds


        proc mixed nobound;
          class rep row col treat;
          model yield = treat;
          random rep row(rep) col(rep);
          lsmeans treat;
NOTE: Estimated G matrix is not positive definite.
NOTE: At least one W.D format was too small for the number to be printed. The
      decimal may be shifted by the "BEST" format.
NOTE: The PROCEDURE MIXED printed pages 1-2.
NOTE: PROCEDURE MIXED used:
      real time           15.829 seconds
      cpu time            8.180 seconds


          /* sas-3-1.sas.  Gradients in rows */
        options ls=78;
        data;
          infile 'lsgr1645.dat';
          input yield rep row col grad treat;

NOTE: The infile 'lsgr1645.dat' is:
      File Name=/home/jb/wk/federer/lsgr1645.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=1236

NOTE: 80 records were read from the infile 'lsgr1645.dat'.
      The minimum record length was 13.
      The maximum record length was 16.
NOTE: The data set WORK.DATA1 has 80 observations and 6 variables.
NOTE: DATA statement used:
      real time           0.273 seconds
      cpu time            0.072 seconds


        proc glm;
          class rep row col treat;
          model yield = rep row(rep) grad*row(rep) treat;
          lsmeans treat;
NOTE: The PROCEDURE GLM printed pages 1-3.
NOTE: PROCEDURE GLM used:
      real time           0.156 seconds
      cpu time            0.132 seconds
```

```
        /* sas-3-2.sas.  Gradients in rows */
      options ls=78;
      data;
        infile 'lsgr1645.dat';
        input yield rep row col grad treat;

NOTE: The infile 'lsgr1645.dat' is:
      File Name=/home/jb/wk/federer/lsgr1645.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=1236

NOTE: 80 records were read from the infile 'lsgr1645.dat'.
      The minimum record length was 13.
      The maximum record length was 16.
NOTE: The data set WORK.DATA1 has 80 observations and 6 variables.
NOTE: DATA statement used:
      real time           0.072 seconds
      cpu time            0.071 seconds


      proc mixed;
        class rep row col treat;
        model yield = treat;
        random rep row(rep) grad*row(rep);
        lsmeans treat;
NOTE: Estimated G matrix is not positive definite.
NOTE: At least one W.D format was too small for the number to be printed. The
      decimal may be shifted by the "BEST" format.
NOTE: The PROCEDURE MIXED printed pages 1-2.
NOTE: PROCEDURE MIXED used:
      real time           0.374 seconds
      cpu time            0.207 seconds


        /* sas-3-3.sas.  Gradients in rows */
      options ls=78;
      data;
        infile 'lsgr1645.dat';
        input yield rep row col grad treat;

NOTE: The infile 'lsgr1645.dat' is:
      File Name=/home/jb/wk/federer/lsgr1645.dat,
      Owner Name=jb,Group Name=staff,
      Access Permission=rw-------,
      File Size (bytes)=1236

NOTE: 80 records were read from the infile 'lsgr1645.dat'.
      The minimum record length was 13.
      The maximum record length was 16.
NOTE: The data set WORK.DATA1 has 80 observations and 6 variables.
NOTE: DATA statement used:
      real time           0.073 seconds
      cpu time            0.075 seconds


      proc mixed nobound;
        class rep row col treat;
        model yield = treat;
        random rep row(rep) grad*row(rep);
        lsmeans treat;
NOTE: An infinite likelihood is assumed in iteration 1 because of a
      nonpositive definite estimated V matrix for Subject 1.
NOTE: Estimated G matrix is not positive definite.
NOTE: At least one W.D format was too small for the number to be printed. The
      decimal may be shifted by the "BEST" format.
NOTE: The PROCEDURE MIXED printed pages 1-2.
NOTE: PROCEDURE MIXED used:
      real time           15.607 seconds
      cpu time            11.016 seconds
```